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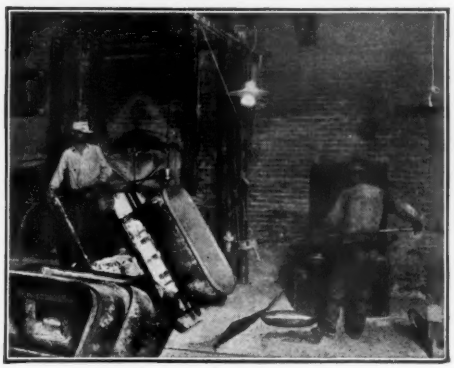

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THE BULLETIN

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of Technical, Scientific, and Art Questions

Vol. 13 July, 1934 No. 7

EDITORIAL

EQUAL THERMAL HISTORY IS ESSENTIAL TO SECURE UNIFORM AND DEFINITE PROPERTIES OF CERAMIC WARE

Emphasis has been given[1] to the importance of "thermal history" in obtaining with certainty the desired and required properties in ceramic ware. The importance of "uniform thermal history" has been realized by producers of glass and they obtain this by controlled diffusion combustion.

A luminous flame results from diffusion combustion, hence diffusion combustion is often called "luminous combustion." Because of the common experience with kitchen stove gas burners where luminous burning of gas soots the pans, some have erroneously concluded that a diffusion combustion flame is a reducing flame and one that will produce soot or solid carbon deposition.

Diffused combustion can be obtained in ceramic kilns with coal, oil, or gas. It is the delaying of complete combustion until the gases reach the ware. Sufficient combustion takes place in the fire box or at the burners to produce CO and H. A small amount of carbon is also produced. To burn these combustion products, air is admitted but not mixed with them, the combustion products being fully oxidized only as the stream of CO and H joins the air stream or as the streams are forced to mix by impact. From this fact comes the term "contact combustion."

The rate of heating and the extent to which a periodic or tunnel kiln can be heated uniformly depends on the amount of fuel supplied and its B.t.u. value. By properly proportioning the primary and secondary air and by suitably regulating the draft, the amount of heating units or combustion products drawn into the kiln can be increased without throwing out of balance their distribution throughout the kiln chamber.

By "controlled diffusion combustion" kilns can be fired as rapidly as is compatible with uniform heating throughout the piece of ware by conduction. The kilns may be uniformly fired in all parts and under oxidizing conditions.

This ideal condition for uniform thermal history, which is so essential to securing uniformly definite ware properties, is being obtained in modern kiln practice in both tunnel car and periodic kilns. It is becoming common practice.

It requires no more fuel and no longer firing period, the fuel consumption and firing rate depending more on the temperature to be attained and the conduction of heat uniformly through the ware being fired.

Unfortunately, most kilns, periodic and car tunnel, are not so fired as to give the uniform thermal history required to develop to the maximum (and repeatedly) the desired properties of the ware being fired. That thoughtful attention may be directed to this essential step in ceramic ware processing, a symposium is planned for the 1935 Annual Meeting of the American Ceramic Society next February in Buffalo.

What are the benefits which will accrue from giving uniform thermal history to pottery of all sorts, to porcelains of all kinds, to terra cotta, wall and floor tile, to refractories, to paving brick, and to enameled iron and steel? Will uniform thermal history make each of these ceramic products more stable under the conditions of their use; more resistant to thermal changes and to mechanical and electrical stresses; less liable to craze, dunt, spall, or spit off; less variable in their chemical and physical resistance to destructive slags and chemicals?

[1] *The Bulletin*, p. 151 (June, 1934).

PAPERS AND DISCUSSIONS

COAL REQUIREMENTS OF VARIOUS CERAMIC WARE IN FIRING*

By Ellis Lovejoy

ABSTRACT

The author discusses the conditions which affect fuel consumption in kilns and the futility of fuel data without full analysis of the conditions. Ideal coal for ceramic kilns, the effect of sulfur, and some combustion problems are also considered.

I. Introduction

There are data on kiln fuel consumption scattered throughout the literature, in the *Transactions of the American Ceramic Society*, the trade journals, the N.B.M.A. bulletins, and especially three bulletins, "Burning Problems of Industrial Kilns," "Problems in Firing Refractories," and "A Survey of Ohio Factories." The latter bulletin covers data on about three hundred factories. It would be difficult to collect all of this literature and it is doubtful if such work would be worth while. Engineers might find such information valuable in developing new factories and others might use it to advantage in seeking comparisons with their operations. But there would be little of specific value because of the numerous conditions which affect fuel consumption. These conditions were read in presenting the paper but being well known they are deleted in the publication.

II. Coal for Ceramic Use

Rice[1] presents an analysis which is the average of eighty coals considered good for ceramic kilns. From these data, with only fractional changes, he develops an assumed analysis of an ideal coal for ceramic use. This analysis is as follows: moisture 2%, volatile matter 36%, fixed carbon 56%, ash 6%, sulfur 1%, fuel ratio (fixed carbon divided by volatile matter) 1.53, calorific value 14,000 B.t.u., softening temperature of ash 2600°F.

There is no fault in such a coal provided its cost is not above its comparative value.

Rice[1] states that the danger of "sooting" is less with a fuel ratio above 1.5. Sooting has often been experienced, but when the user is troubled with it, a coal having a high fuel ratio, that is, anthracite or smokeless coal, is substituted.

The high softening temperature of the ash is commended. The fusion of coal ash ranges from 2000 to 3000°F and the higher this fusion temperature the less trouble there will be in closed draft through the fires and in clinkering. On the other hand, for grateless furnaces a clinker is required to build up the front which holds the furnace coals. This front is the equivalent of the inclined grate-bar front.

There is no objection to 14,000 B.t.u. Such high-value coals are available, but the average coal falls below this value. The average of the above-mentioned eighty coals has 13,540 B.t.u. Another analysis presented (said to be the best coal in the United States for ceramic kilns) has a British thermal unit value of 12,500. Of a list of sixty-nine coals from twenty-one states, presented in an engineering handbook, thirteen, or one out of five, have analyses with 14,000 B.t.u. Eight of these coals are from West Virginia, two from Virginia, two from Pennsylvania, and one from Kentucky. Coal should be bought on a British thermal unit basis, but a premium can not be paid for values higher than an average of a good coal.

III. Sulfur-Scum Relation

Rice states that the scum does not occur if the clay does not contain lime or if the concentration of sulfur in the gas is low; hence a coal that contains a low percentage of sulfur is desirable.

This statement regarding the lime content is debatable. Scum is a complex body and though lime sulfate generally predominates, there are notable quantities of other combined and fused salts. Palmer[2] presented a scum which is chiefly an alkali sulfate designated as "fixed scum."

Kiln firing does not produce scum and the content of sulfur in the kiln gas, insofar as high and

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[1] W. E. Rice, "Properties of Coal in the Ceramic Industry," *Trans. Amer. Inst. Mining Met. Engrs.* (Coal Div.), 1932.

[2] L. A. Palmer, former Research Fellow, Bureau of Standards.

low sulfur coals are concerned, is of no consequence. Scum is brought to the surface of the ware as an efflorescence, and it must be in solution to so come out. Therefore it can not come out in the firing. Although a great quantity of scumming salts is developed inside the ware during the firing, they remain in the ware and in the final stages of the firing are recombined into permanent silicates.

The water-smoking stage of the firing is the final stage of drying and should not be considered in connection with the actual firing. Scumming salts will develop in the water-smoking, and if the ware is wet they will come to the surface and become scum. This is the same as the scum development in the drier in the presence of sulfur gas in the drying atmosphere. If the ware is dry and clean when set in the kiln there is little danger of scum; there should be none.

Scum development in water-smoking should be considered in its relation to sulfur content in the kiln gases.

When water vapor is coming off the ware there is but shallow penetration of the kiln (sulfur) gases or of acid condensations from the kiln gas. The depth of penetration below the surface of the ware is scarcely $^1/_8$ inch. (The writer has never seen a greater penetration than $^1/_4$ inch.)

It is questioned whether there is any coal so low in sulfur as to be insufficient to convert into sulfates all the bases in the surface of the ware. If not, then any coal, however low in sulfur, will develop the scumming salts on wet ware whether in the drier or the kiln, and any sulfur in excess of this quantity is merely inert excess.

If high sulfur in the kiln gases causes scum, few ware made from shales and fire clays would escape scum in the firing. Such clays are seldom free from pyrite. Jackson[3] showed a high development of scumming salts in the clay mass during the expulsion of the combined water, but they are not brought to the surface. With such clays there is excessive sulfur in the kiln gases and a small amount in the coal will make no difference.

Scum can not be prevented by using low-sulfur coal since there is no coal available for general use so low in sulfur that it will not develop scum under the conditions which lead to scum.

[3] F. G. Jackson, "Descriptive Bibliography of Scumming and Efflorescence," *Bull. Amer. Ceram. Soc.*, **4** [8], 376–401 (1925).

Rice's statement in effect appears again in a paper by Nold.[4]

IV. Combustion

Nold also states in effect that combustion is completed within a few feet of the furnaces and that the luminous flame seen in the kiln and often at the stack tops after firing is due to incandescent soot and fly ash.[5] Careful study of the bulletin cited does not fully confirm such a positive conclusion.

It is commonly thought by clayworkers that luminous flame is due to burning combustible gas carried over into the kiln, and this idea is confirmed by several tests.

Combustible gases in the presence of free oxygen are commonly shown in the flue-gas analyses of this bulletin.[5] These are averages of hourly samples, and are not conclusive. In one instance, however, ten-minute samples taken as a check are conclusive. This conclusion was verified by the writer in an investigation continued over a year in an operation where every effort was made to get completed combustion in the furnaces.

The furnaces described by Rice, the grateless, the inclined grate, and the deep fuel bed flat grate types are crude and not conducive to completed combustion; they are heavily fired at hourly periods or often less frequently. They are projected about 18 inches into the kiln the full width of the bags, and in some instances the kiln wall is recessed to increase the uncovered fire in the kiln; they are scarcely more than rectangular boxes in the kiln.

The combustion gases, high in combustible gas, rise vertically from the exposed section of the furnace, leaning toward the ware above the low bags. The secondary air enters through the furnace mouth through the top of this opening, over the coal in the grateless and inclined grate types of furnace. It flows through the crown space and enters the bag behind the stream of combustion gas. The secondary air and combustion gases mingle and combine only when and where they are brought into contact. These two streams enter the kiln crown space and are drawn down through the spaced ware where thorough

[4] Presented before the American Institute of Mining and Metallurgical Engineers by H. E. Nold, Secretary, Ohio Ceramic Industries Association.

[5] Nold cites in confirmation, "Problems in Firing Refractories," *Bur. Mines Bull.*, No. 271, by W. E. Rice and G. A. Bole.

mixing and complete combustion take place. The mixture, however, depends upon the proportions drawn in among the ware. The downward movement is largely vertical and the mixtures entering the ware at the top will be in the same (burned) proportions at the bottom.

If the air is in excess the flue gas will contain free oxygen and no combustible gas. If the combustible gas is in excess it will show in the flue gases. It is extremely unlikely that the accidental collection of the top gases over the large kiln area will be in the proper proportions, especially if the total excess air is limited. If not, combustible gas and free air will be entering the flues. Many gas analyses show this to be the case.

(1) Equalizing Heat Distribution

Rice[1] agrees with the clayworkers' view. In regard to the distribution of heat to mature every part of the charge in the kiln, he says

> This can be accomplished...with a coal which has a high content of volatile matter...and which burns with a long radiant flame, so that a large area of the charge is heated by radiation...with such a coal...the firing of the kiln is done without overheating the furnace.

If the combustion were completed in the furnaces, the heating of the ware in the kiln would be accomplished by convection rather than by radiation.

If completed combustion is obtained in the furnaces, the furnaces will be hot. With a large percentage of the volatile gas carried over into the kiln room with accompanying air, the furnaces are comparatively cool and long-lived.

Flashing is accomplished by limiting the secondary air and burning the combustible gas among the ware. The gas will get oxygen in a varying degree from the ware minerals as the term "reducing" implies. There is invariably some flashing no matter how much effort is made to avoid it, and the assumption that accidental flashing comes about in the same way as intentional flashing is justified, which indicates that it is difficult to secure completed combustion in the furnaces.

Soot burns slowly, except in a flame temperature; yet it is quite likely that it causes some of the luminous flame. The soot period in the firing interval coincides with the volatile gas, and the flame is attributed chiefly to the latter.

It seems improbable that fly ash affects the flame. Ash comes off with the combustion of the fixed carbon. It is therefore at a maximum during the later part of the firing interval when there is no flame. When the bed of incandescent coals is covered with fresh fuel the fly ash going over into the kiln will be at a minimum, and this is the period of the flame.

V. Conclusion

Should many clayworkers be convinced that a low-sulfur coal will prevent scumming, they would go to considerable expense to secure such a coal, but without benefit in the writer's opinion.

If clayworkers believe that combustion is readily completed in a crude furnace, they may construct such furnaces in place of the more effective types, they may abandon careful firing (the purpose of which is to get completed combustion), they may adopt cheaper coals, and in the end suffer loss in the ware. If the authorities quoted are correct, the clayworkers may profitably do these things.

One important point emphasized in the citations which is worth mentioning is that heat transferred to the ware by radiation is decidedly more effective than the transfer by convection. The former comes from a radiant flame (combustible gas), from incandescent soot, and fly ash. The latter is merely a mechanical transfer of the specific heat in the furnace gases to the ware.

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OUTLINE OF WORK OF REINFORCED BRICK MASONRY RESEARCH BOARD*

By F. E. Richart†

The Reinforced Brick Masonry Research Board was organized in December, 1932, and is sponsored by the Brick Manufacturers Association of America, the American Face Brick Association, and the National Paving Brick Association. Its membership includes F. E. Richart, *chairman*, Hugo Filippi, *secretary*, and H. G. Balcom, G. S. Eaton, S. C. Hollister, T. R. Lawson, D. E. Parsons, M. O. Withey, and G. S. Schlesinger.

The Research Board has as its ultimate object the collection of scientific information on all types of reinforced brickwork so that logical rules of engineering design may be formulated. To this end it has outlined a limited research program, much of which is being carried on by members of the Board, and plans in the future to initiate and unify other research projects which may be carried on by any coöperating laboratory or agency. It aims to avoid undue duplication of tests, and, with the very extensive literature of reinforced concrete available, it will attempt to save much work by establishing correlations between the behavior of reinforced brickwork and reinforced concrete.

Two projects under the Board's test program are now in progress. The first, a test of reinforced brick masonry columns, is being conducted by Professor Withey at the University of Wisconsin. Most of the group of 27 columns are about 13 inches square and 6 feet high, while a few are to be 12 feet high. Two grades of common brick are used with one grade of mortar. Vertical reinforcement is provided in amounts of 0, 2, and 4% of the cross-sectional area, and columns are made with and without lateral reinforcement in the form of circular hoops, placed in each horizontal mortar joint.

The second project is under the direction of Professor Richart at the University of Illinois. It consists of tests of thirty reinforced concrete beams, designed to produce high vertical shearing stresses. They are about 8 by 20 inches in section and are tested on an 8-foot span with a $^1/_3$-point loading. Two types of common brick are being used and there are two variations in longitudinal reinforcement and several amounts of stirrup reinforcement. Stirrups of Z-type are used, with the body of the stirrup placed in the middle vertical mortar joint of the beam.

In both of the investigations, several auxiliary test pieces are used. Various members of the Board are experimenting with these with the object of developing them as standard control specimens. They include the following specimens: (1) Masonry prisms, 25 inches high and 8 inches square, with three courses of brick set on end, so that they will be loaded endwise in a compression test of the prism. The ends are capped with plaster of Paris or a strong mortar before testing. Such prisms give the strength and modulus of elasticity of the masonry as it is loaded in a beam. (2) Flexural bond specimens, consisting of a stack of five brick laid in mortar. When cured, a stack is laid on side and tested as a simple beam with center loading on a 10-inch span. The modulus of rupture so determined is a measure of the tensile adhesion of mortar to brick. (3) Shearing bond specimens, consisting of a stack of three brick, laid in mortar. When cured, the stack is laid on edge and so supported that the middle brick may be pushed out from between the other two. To avoid flexural failure a spring clamp is used which applies a 50-pound force to the faces of the two outer brick. This provides a fairly constant frictional force in addition to the shearing adhesion between brick and mortar. (4) Mortar specimens, consisting of 2-inch cubes or 2- by 4-inch cylinders, are tested in compression to furnish a measure of the quality of the mortar.

A number of other test projects is being considered by the Research Board. Probably the most important is a study of masonry mortars and a correlation of the properties of mortar most suitable for use with various kinds of brick. Work now in progress at the Bureau of Standards indicates that the kind of mortar to be used depends upon the rate of absorption, the texture of the brick, and other considerations. Attention is being given to producing mortars with water-holding properties, as well as to finding the mois-

* Presented at the Annual Meeting, American Ceramic Society, Cincinnati, Ohio, February, 1934 (Structural Clay Products Division). Received February 15, 1934.

† Research Professor of Engineering Materials, University of Illinois, Urbana, Illinois.

ture content of brick which will give the optimum conditions for bonding. Study is needed on new types of brick surface which may provide increased bond.

A series of tests considered would be made on the bond between mortar and reinforcing steel, with especial attention to the thickness of the mortar joint in which a bar is embedded. In such tests, in addition to the usual plain and deformed bars, various types of flat bars should be used.

Naturally, many other tests to determine strength and elastic properties of various members are needed, and the Board will welcome assistance both in the planning and carrying out of researches in the field.

ORIGIN AND MANUFACTURE OF CALIFORNIA'S CLAY ROOFING TILE*

By Ross D. Plank

I. Introduction

As long as man used a flat roof, tile was impractical. The sloping roof, however, was possibly developed before the Iron Age and is shown by cinerary vessels in the form of huts found in excavations in Italy, Saxony, and southern Europe. The fired clay first used was possibly bits of broken pottery. Later, pieces were fabricated for the purpose, leading gradually to the tile as it is now known. Thus the early potter invented the most durable form of roofing which neither rusts, decays, nor burns, and often is the only remnant of dwellings left to the archeologist.

Improved only in technical production details, in actual form and use tile has been known for centuries. One of the most common forms in use today was described by Groeber as being the most ancient known. In his memoirs, Terra Kottem an Giesch, he describes what he believes to be the earliest known tile, found in the ruins of the Temple of Hera at Olympia dating about 1000 B.C.

II. Historical Survey

The ancient covering consisted of two units, a wide underpiece or pantile (tegula) which curved slightly upward, and a more narrow semicylindrical piece or top tile (imbrex) which was inverted to cover the space between two of the former units. While these tile are possibly the most authenticated examples of ancient tile roofing, it is not to be supposed that the Greeks progressed directly from the thatched roofing to this efficient style of roof covering. It is known that the origin of many of their other arts, metal-working, pottery, etc., lay in the older civilizations of Asia Minor and China and while the genius of the Greeks developed all of these to a plane never before known to the world, they can not be credited with their invention.

The method of the early use of tile is rather misty, but the use of potsherds imbedded in the earthy coverings possibly led to the gradual replacement of the earth or mortar by the tile so that, from being only the covering, the earth remained as a binder and filler holding the tile in place and filling the interstices.

Probably roofing tile, like many other devices of man, were developed simultaneously by various peoples. Among the materials used for the roofs of 650 B.C. are marble tile worked to the same shape as that used for clay. In the story of Ben Hur, Lew Wallace depicts the Roman governor being struck by a roofing tile as he passed along the street. Gradually, through simultaneous development or carried by aggressive users to conquered lands, the use of roofing tile became common throughout all Europe, each country adopting a form best suited to its own particular needs and tastes. The moderns have added various interlocking tile of more complicated designs as well as the shingle.

III. History of Roofing Tile in America

(1) Pennsylvania When roofing tile was first introduced into this country it was only natural that they should be brought from the parent country or should be made here after patterns in use in the homeland. The flat tile made in Montgomery County, Pennsylvania,

* Presented at a meeting of the Pacific-Northwest Section of the American Ceramic Society. Received July 15, 1933.

about 1735 can be traced to the old German settlers. In Bethlehem, Pennsylvania, the Moravians were making tile as early as 1740. The pantile discovered on Burlington Island in the Delaware River on the site of an old home built by Peter Jagen points clearly to the Dutch settler as its maker.

(2) Ohio In Germantown, Ohio, John Robison started a brick plant about 1820 and made, among other products, enough crude shingle to cover his house and stable, which stood until 1907. The Zoarites, a German religious sect, in building their settlement of Zoar about the same time, made a "beaver-tail" shingle whose style can be traced back to their native town of Würtemburg. They prepared this clay in a soaking pit by treading it with their feet to the desired consistency, later shaping the tile in wet wooden molds sprinkled with sand by packing a piece of clay, shaped like a loaf of rye bread, in the mold with their hands and cutting off the excess with a stick. Some of the tile were plain and some were finger-marked to suit the fancy of their maker and to keep the rain away from the joints. The tile were fired in updraft kilns similar to those in use at the present-day soft-mud plants.

(3) First Interlocking Tile Plant In 1871, J. B. Hughes of Terre Haute, Indiana, received the first letter patents on an interlocking tile and also for a machine to prepare them.

(4) California While the early settlers in the eastern part of the country were developing a covering suitable for their dwellings, the same thing was taking place in California. The style of California architecture was established by the padres of Spain and reflects its origin to the Italian and Spanish source of its conceptors, its roots going deeply into lands surrounding the Mediterranean. The Jesuits, an order founded by Ignatius Loyola in 1534, established eighteen missions in California from 1697 to 1767. They were then expelled from all Spanish territory and their place was taken by another similar group, founded in the 13th Century by Francis Assisi, called the Franciscans and commonly referred to as the Gray or Barefooted Friars. In charge of their California activities was a man of unusual capabilities who occupies a prominent position in the history of early California, Padre Junipero Serra, and under his guidance the Mission of San Diego was founded in 1769. Following that mission a chain of twenty more was added about a day's journey apart along El Camino Real (the Royal Road), extending from San Diego on the south to Sonoma, just above San Francisco Bay on the north, all comprised in a strip of coast somewhat over 500 miles in length, which was the Alta California of Spanish days.

When the padres decided to erect their early California dwellings they found themselves in a country peculiarly deficient in the more easily worked materials. Trees for timbers were lacking, particularly in the south, so they turned to the use of the most easily prepared material available, one that could be fabricated by the crude fuels and workmen at their disposal, the earth. Whether or not they adopted the use of this earth or *adobe* from the practice of the Indians, or whether they developed the use of the materials at hand independently is not known, nor the extent to which they drew on observations in the homeland. Had adobe been in itself a suitable roof covering, the fired tile would not have been used for many years.

There is a tradition that the roofing tile were shaped over the human thigh as a mold, but the real mold is thought to have been made of wood. Over this mold or form, a clay blank was pressed into shape by the hands and a hole was made in the end. The form was then withdrawn leaving the tile to dry. The blank was formed by pressing clay into a frame laid on a flat surface previously sanded and by cutting off the excess with a stick as was done by the Pennsylvania settlers. Part of the sand adhered to the blank making it possible to lift it from the frame and to keep it from adhering to the form. The kilns were probably built of the same materials in the most crude style, for the tile fired in them were little more than sun dried in comparison with the present-day products. But they were durable since many of them are in excellent condition after two hundred years or more of service.

These tile were fastened by leathern thongs passed through a hole in one end and tied to the rafters, but there was no means of preventing an occasional adverse wind from forcing rain underneath them, as has the present-day tile.

The tile from the different missions show a difference in workmanship as well as color, due to variations in raw materials and treatment. Stones are often found in them with a diameter

equal to the thickness of the tile themselves, and these stones are also present in the fired brick and floor tile. There were no screens and the stones were thrown out as the clay was being worked by the hand or foot.

Many of the tile are moss colored, usually a typical yellow-green moss color, but with the green are also gray, black, and orange. Some of the tile are beautifully colored even to close inspection.

Today in some small plants in California, roofing tile are made in much the same manner as those of the missions, one plant even using animal power to temper the clay. They fire their ware in crude updraft kilns which give a density and hardness similar to those of the old missions. These plants are often family affairs where the weekly washing waves from a line in dangerous proximity to the spattering mud of the hand molders.

(5) Machine-Made Roofing Tile In contrast to the methods used by the padres, at a modern plant making roofing tile, clay, which is properly ground, screened, and tempered with water, is fed directly into auger tile machines. These are equipped with dies to produce the various contours of the different tile.

After leaving the die the clay ribbon is automatically cut into the proper lengths and holes are punched. From these machines the tile are taken by men using forks which fit the shape and are placed in racks on drier cars. The cars pass through the humidity drier into the kiln.

In the kiln, for the first time since entering the plant, the clay is touched by human hands when the tile are taken from the cars and set either in periodic downdraft kilns or on cars for the tunnel kilns. From the tunnel kilns, they emerge in three days to be piled ready for shipment.

Most of the machines extrude a single column, but some send out a multiple tile often in the form of hollow tile or elliptical pipes, scored to be broken either before or after firing, depending on the mode of their setting. One of the popular modern tile made in this fashion, the Granada, has the same shape as the pantile from the Temple of Hera, and is used for both pantile and cover tile.

Some of the tile are formed by hand in a manner similar to those of the mission tile. The clay is tempered softer by the process just described but instead of being shaped into tile by machinery it is carried by an electric lift truck to the hand molders. Here paper takes the place of the ancient sand and over it is laid a metal frame the same thickness as that desired for this tile. This is filled by hand with soft clay and the excess is struck off with a stick as this gives a packing action not to be obtained with a wire. Then paper side down, it is pushed off onto a form against which it is forced by hand and rubbed down to a good fit, stamped, a hole punched, and placed on a drier car. From here the process follows that of the machine-formed tile. When finished these tile resemble the ancient ones in form only, being more uniform yet variable enough and with a texture to give a distinctly different appearance from that of a machine-formed tile. They are harder fired, their absorption being carefully watched, and they will stand a freezing climate which the earlier tile, intended only for the milder climate of California, will not. They are produced not only in reds, but in browns, purples, and gun metals of flashing. Hand-molded tile are also made like the early Chinese or Italian tile and, like the shingle tile, in various textures and sizes, including that of the cedar shake.

(6) Glazed Roofing Tile The colors imparted by slips and glazes have been added particularly in the last few years to all the various-shaped tile, sometimes to produce a vividly colored roof and sometimes to produce the effect of time and weather, giving the aging effect of centuries to a newly laid roof.

(7) Antique Colors and Textures Considerable attention has been given to the development of antique colors and textures in many shapes, and slips and stains (not glazes) are used for these. One of the first, called the Cuban, was prompted by the importation into Florida of roofs taken from old dwellings in Cuba and its tile were the shape of hand-made mission tile. The predominant color is gray, splashed on in a uniformly varied manner, while some have a green aggregate thrown into the soft clay. Others have gray, green, or black rubbed onto the tile while a few have their natural color. This same color is applied to many different shapes.

A different effect was copied from some old tile taken from an ancient dwelling in Florence, Italy. The top tile is less cylindrical, having more of a peaked cross-section and the pantile are flat.

The Italian tile are partly covered by gray and black moss.

One building on which the modern duplication has been laid, a mausoleum whose permanence is assured as nearly as present-day ingenuity can, shows a modern method of tile laying. The roof itself is of reinforced concrete in which is imbedded copper wires, protruding as loops through a heavy covering of tar paper. Through these loops run heavier copper wires parallel with the eaves and to these the tile are fastened by short copper wires.

(8) Tile Roof Design Unlike the mission roofs, all present-day roofs have or should have a first covering of composition roofing paper and the tile should be either wired or nailed in place on it. Mortar is occasionally added. A random style of laying most hand-made tile is usual, in which the lines of the rows and tiers are broken up by uneven placing of the tile. This is in contrast to the even placing where the rows run straight up the roof and the tiers are parallel to the eaves. Either style can be used with machine-made tile but the random style is best adapted to the hand-made tile.

Some roofs are shaded, darker colors at the eaves and lighter higher up, while different sizes are often used in the same way, the larger at the eaves giving the appearance of greater size. This antique effect has been carried into shingle tile with many different colors and combinations.

The appearance of aging has been heightened by the addition to the plastic tile surface of combustible material which, when fired out, gives a realistic weather-worn appearance. In the production of glazed and slipped tile care is taken to maintain uniform results even with the antique effects, which to casual inspection are anything but uniform. Whether the advantage of a greater variation to give a more individual appearance would be over-balanced by the disappointment of the client who has selected the effect of some particular existing roof is a debatable question.

(9) Color and Texture Green is the most popular color, particularly for the glazed tile, and the shiny texture is more popular generally than the mats or satins. In Honolulu, however, mat and satin texture is preferred, and for color, blues with a green tinge or a vivid blue. The preference there for blues over green is due to the luxuriant tropical verdure.

More gray-slip tile are also used there than on the mainland, similar to shades used in China.

Colors used other than greens and blues include blacks, yellows, browns, reds, turquoise blue, and orange.

Acknowledgment The author wishes to acknowledge data on the history of eastern tile taken from Geological Survey of Ohio, 4th Series, Bulletin No. 11.

GLADDING, MCBEAN AND COMPANY
LOS ANGELES, CALIFORNIA

ACTIVITIES OF THE SOCIETY

Officers of the Industrial Divisions

L. E. Barringer, Charles Harder	Art	R. C. Meeker, H. B. DuBois	Materials and Equipment	J. L. Carruthers, D. A. Moulton	Structural Clay Products
W. N. Harrison, B. J. Sweo	Enamel	H. E. White, R. E. Birch	Refractories	H. D. Callahan, H. E. Davis	Terra Cotta
James Bailey, F. C. Flint	Glass			Edward Schramm, T. A. Klinefelter	White Wares

GLASS DIVISION SUMMER MEETING, SEPTEMBER 14–15

(1) Meetings: At Hammondsport, on the south shore of Lake Keuka in the champagne country of New York.

(2) Bunks: At Willow Point one mile up the west shore in nine cottages.

(3) Guest of Honor: William Ernest Stephen Turner, Secretary of the Society of Glass Technology (England).

(4) Topic for Discussions: Glass corrosion.

(5) Forms of Recreation: Boat races, swimming, and beach breakfasts.

(6) Committee on Arrangements: Littleton, Bowes, Flint, and Bailey. Hammondsport's Chamber of Commerce, E. B. Jaycox, president, is working with this committee. (Mr. Jaycox, incidentally, is Secretary of the Pleasant Valley Wine Co., makers of Great Western Champagne.)

(7) Historical Background: Glenn H. Curtiss made historic experiments in aeronautics here.

DIFFUSION COMBUSTION—WHAT IS IT?

Rapid Heat Transfer and Uses of Diffusion Flame Combustion[1]

One characteristic possessed by an oil flame is its intense luminosity. To this is due its ability for rapid heating at high temperatures, the heat from the incandescent carbon in the flame being transferred to the work largely by radiation. When, however, gas and air are premixed for combustion, which is general engineering practice at this time, there is almost a total absence of flame and unless the burning gas impinges directly on the work the heat is imparted to the work mostly by the slower process of convection. The usual city gas or natural gas contains an appreciable amount of organic carbon which it is possible to separate out as such if the gas be heated to a high temperature in the absence of air. The real problem was to devise a method whereby this separation could take place within a furnace and concurrently with combustion.

Such a method has been evolved during this research, and applied in practical furnace operation. By a process of "diffusion flame combustion" the gas is caused to burn with an intensely luminous flame which is highly radiant within itself and in its application is more readily controllable than an oil flame. Diffusion flame is a term applied by Burke and Schumann to those gas flames in which the air for combustion reaches the gas by diffusion through the burning flame rather than by any form of premixing; that is, the air and gas unite and combustion takes place progressively as the air meets unburned gas. The phenomena should not be confused with ordinary "luminous" burning of gas. The very means employed in bringing about diffusion combustion in the forging research also made possible the segregation of a portion of the fuel gas which was caused to sweep over the work being heated and to protect it from the effects of the products of combustion. This layer or blanket of gas can be so controlled that steel can be heated by this method to very high forging temperatures with a total absence of scale.

The application of this method to forging operations involved the development of a new technique in burner construction and furnace design which has been considerably retarded by the lack of suitable materials of construction. By slow stages various materials have been tried and tested under actual practical conditions resulting in evolving a type of burner which has effectively interpreted this combustion process in a reasonably satisfactory manner. The problems arising from unsatisfactory refractories have made the construction of a suitable furnace a task requiring gradual evolution. This problem is now, however, in a fair way to a practical solution.

As stated above, in diffusion flame combustion the flame itself becomes a pronounced source of radiant energy. Since oxygen is not initially present in sufficient quantities, the hydrocarbons of the gas break down into hydrogen and free carbon; the latter is heated to incandescence by the progressive combustion of the surrounding gases, thus becoming the source of the luminosity of the flame. The intensity of the luminosity of such a gas flame is at least equal to that of an intense oil flame. By working out proper designs of the diffusion flame burner, an emissivity factor as high as 0.6 has been secured. The importance of a high emissivity is pointed out by Stefan-Boltzmann's law, which states that the rate of heat transmitted by radiation is directly proportional to the emissivity of the radiating body. Since the energy transmitted is also proportional to the fourth power of the absolute temperature and as the flame has a high emissivity factor, it follows that only a small temperature difference is sufficient to cause a considerable rate of heat transfer. Practically, this means that a relatively low temperature head will permit a large percentage of the furnace heat to reach and penetrate the work to be heated.

In such applications as glassmelting, radiant heat from diffusion flame combustion will penetrate through the entire mass of the glass, thus heating the mass very uni-

[1] Reprinted in part from the Fifth Annual Report, Committee on Industrial Gas Research, June, 1931, pp. 17–21.

formly and more rapidly than is possible when the entire heat transfer is by means of convection. An important characteristic of the radiant heat available from diffusion flame combustion is that it will penetrate the blanket of nonburning gases with which delicate work should be surrounded. Thus, material can be heated by the direct rays from the flame without fearing any of the detrimental effects sometimes caused by having the work come in contact with violent combustion.

The Committee on Industrial Gas Research believes that when diffusion flame combustion is developed to its full possibilities, industrial gas men will have a new tool by which they can compete with other fuels in a way heretofore impossible. The combustion of oil has inherently some of the characteristics of diffusion flame combustion, and in many instances because of this fact, industrial gas men have been forced to use more B.t.u.'s from gas in a given operation than it has been necessary to use with oil. Likewise, it has been difficult in some instances to meet the competition of the radiant heat given off by electric heating devices, and it is expected that diffusion flame combustion will prove quite useful in enabling industrial gas men to round out a complete heating service to large factories on an economical basis.

W. M. Hepburn, Surface Combustion Corporation, Letter to the Editor[2]

In connection with the kiln firing discussion you have submitted for my comments, I can say you have chosen a subject which would be most prolific of lively discussions. Discussions of this kind can become most confusing unless the applications to which they apply are clearly defined. For example, the type of combustion which gives the best results in a periodic kiln would not necessarily be the best type for a tunnel kiln.

The point which you have brought out regarding the effectiveness of delayed combustion in a periodic kiln is one which those who have had experience will appreciate. It is easy to gain the viewpoint, from the very effective results secured with simple equipment such as pipe burners and secondary air, that a more scientific approach such as offered by the diffusion combustion would eliminate or minimize the disadvantages of the more crude applications. This again might not necessarily be the case. The more scientific aspects of the diffusion combustion have been mainly concerned with greater rates of heat transfer and protective atmospheres and might not contribute the advantages required in the periodic kiln, namely, more accurate control and greater uniformity of heat distribution.

On the other hand the advantages of more automatic operation of the premix equipment can not be fully realized in a large periodic kiln due to the localization of heat or the too intensive impingement against the ware.

The Lenox installation, for example, is a case where advantages of the automatic proportioning equipment can be fully utilized. The construction of the kiln is such that the ware is protected from the direct impingement of burning gases, but this baffling of the combustion zone has not imposed any muffle limitations on the construction of the kiln due to the proved fact that the flue gases have no injurious effects on the ware and evidenced by the fact that a walking beam mechanism is utilized for conveying the material through the furnace.

In other words, each type of installation should be analyzed separately for its best application. It would be my comment that the discussions most beneficial in bringing out in just which direction the best progress can be made in kiln firing would require a careful bracketing of the type of kilns which have requirements in common.

These are some random thoughts which have come to my mind in acknowledgment of your discussion. In the meantime I shall be glad to give the discussion further thought and get in touch with you later.

[2] June 21, 1934.

Editor's Reply to W. M. Hepburn[3]

You are correct in saying that to avoid confusion there should be a careful bracketing of the type of kilns which have requirements in common.

It should be taken for granted in any discussion of this sort that there are several periodic and tunnel kiln plants that are being fired with an even heat distribution under positive control and in which the ware is receiving equal thermal heat treatment throughout each individual piece and from piece to piece. Such is the practice in most abrasive plants with both periodic and tunnel kilns and in most modern potteries. The principles discussed by me in the June *Bulletin* (in the editorial on p. 151 and in my letter to Mr. Milener on p. 166) differ in no respect from the practices developed through experience in glass factories using the modern pot and tank furnaces.

As related by Horace Crew, equal heat distribution on the cars in the Harrop and in the Dressler kilns, as well as in the periodic kilns at the American Encaustic Tiling Company, was obtained by the use of secondary air to complete the combustion which was purposely delayed to occur within the kiln or within the individual car setting. Mr. Crew told us that when first installed they used premixer burners on their tunnel kilns but later removed most of them.

There has been some misunderstanding of my statements because many ceramists are already employing the principles of kiln firing I set forth and naturally wonder if I am criticizing their practice. My criticism is of the practice of attempting to secure a complete mixture of the gas and of the air required for combustion in the burner and of the attempts of industrial engineers associated with gas companies to sell premixers and expensive burners for gas firing of kilns. Fortunately tunnel kiln designers have control over the equipment and firing methods employed on tunnel kilns, but the industrial gas engineers are active in their attempts to sell expensive equipment to periodic kiln users. The employment of these gives very unsatisfactory service.

Furthermore, my criticisms were prompted by statements made in government reports on kiln studies (which have since been repeated by men connected with universities) to the effect that in periodic kilns the combustion of the gas is completed either in the fire box or a very short

[3] June 27, 1934.

distance from it, and that there is no combustion taking place in the kiln itself throughout the ware. This statement is wholly erroneous when describing the results obtained in those periodic kilns where even heat distribution is secured.

The fact is that the means employed to get even heat distribution in a tunnel kiln car are the same as those that are employed in getting even heat distribution in periodic kilns. So far as the basic principles involved are concerned there would be no separate bracketing of open-fire tunnel and periodic kilns.

My thoughts have not been at all critical concerning the Lenox installation because I have not seen it and I have not read any description of it other than that contained in the correspondence with Mr. Milener. As a matter of fact between the statements made by you and Mr. Milener, my ideas are somewhat confused because Mr. Milener states that it is open-fire and that the products of combustion impinge on the ware, whereas you state that the ware is muffled on the sides and top and that the products of combustion are made turbulent within this muffle. From what you told me I gathered that, except for leakage in the bottom due to operation of the walking beam, the ware in the Lenox kiln is completely muffled, that the muffle is heated by convection, and that the ware is heated by radiation from the muffle.

We have several makes of tunnel kilns in successful operation in this country, and by successful I mean giving equal heat distribution throughout the body of the ware and equal and uniform heat treatment from the beginning of the firing to the end of the cooling. It is this controlled uniformity in heat treatment that makes the tunnel kiln superior to the periodic kiln. Henry C. Kleymeyer, of Evansville, Ind., prefers to fire his face brick in periodic kilns but is obtaining the advantages of the tunnel kiln through specially devised means for preheating by waste heat from the cooling kilns and by controlled distribution of the products of combustion.

In none of these discussions are we thinking about the ridiculous kiln firing that potters have used in times of stress, such as complete turnover of a kiln in thirty-six hours or special cases of very high temperatures in large periodic kilns; this is the case at the Charles Taylor Sons Company, Cincinnati, Ohio, where they get very high temperature for some of their products. Both of these are extreme cases and should not be brought into this present consideration. The fact remains that the method of managing the firing, whether it be by coal, gas, or oil, depends upon the desired rate of heating and the intensity of the heat treatment to be obtained. Since in abrasive-ware firing a schedule of ninety or more hours in periodic kilns 15 to 22 feet inside diameter can be attained on the secondary air principle of firing described by me, it would seem to be common sense that to shorten this time of firing the fuel would have to be supplied more rapidly and a more vigorous draft maintained. But whether firing rapidly or more slowly the fact remains that to secure even heat distribution throughout the kiln, the gases can not be completely burned within the fire box or within a short distance from the fire box but for the most part must be burned within the kiln and among the ware.

Whether using a short or long firing schedule and whether using a tunnel or a periodic kiln, the presence of luminous flame in the kiln does not mean that the ware is being reduced or that there is a great amount of incandescent solid particles. The excess air will prevent reduction of the ware.

The solid carbon cracked from the gas produced from coal or from the gas introduced as such is, in the extreme case, small in amount. It is possible, therefore, to open-fire ceramic ware in both periodic and tunnel kilns using the diffusion-combustion method described by me. Muffled glazed ware need not be more than lightly saggered, the purpose of which is to carry the ware. The biscuit ware can be set exposed on car setting blocks without risk of being damaged from the carbon or the products of combustion in a very large variety of kilns now being used, both periodic and tunnel.

If this whole problem was something new or something that had not already been developed in practice by many of our periodic and tunnel kiln builders and users, my statements regarding diffusion combustion would indeed sound radical, rather than in conformity with the best-known practices. The only value of a symposium such as has been proposed is to broadcast the benefits which are known to have been obtained by this rational method of firing periodic and tunnel kilns to those who apparently are not practicing this economical method and are not securing the desired uniform thermal history for the product which they are producing. It is not for the benefit of the minority but for the majority of ceramic ware producers that the proposed symposium is designed. Furthermore, it is desired to acquaint the ceramic-ware producers with the futility of the methods proposed by industrial engineers connected with gas companies and to reveal the shortcomings of electric kiln firing. There are other purposes of this symposium such as to uncover the problems incident to electric kiln firing of enamelware and the possibilities of even heat distribution and controlled thermal history in muffle kilns for clayware firing.

It is hoped that you will let us have the benefit of your further consideration as well as that of the Research Committee of the American Gas Association.

LETTERS

Meeting of American Federation of Arts
May 14 to 16

. . . I attended all meetings of the American Federation of Arts as representative of the American Ceramic Society . . . although our Society dropped its membership in the Federation in February, I . . . sponsored several proposals of Mr. Whiting for the future aims and purposes of the Federation as if we were still members.

While it is perfectly true that ours is primarily a technical society and covers all the silicate industries, and as such its membership and financial support come preponderantly from members of industries that are not concerned with art, it covers all that is comprised politically in Schedule 2 of the Tariff Law, and the art features are among the most important of the Tariff Commission's deliberations and decisions.

I was a member of the Commission for two years.

From its inception I have been a member of our Society's Advisory Committee on Whiteware, the purpose of which is to work with the Bureau of Standards to determine the fundamental qualities and tests of its raw materials which are general and should be investigated by the government for the benefit of all, and those which should be left for the private initiative of the technicians of the factories.

I am sure this committee would object seriously if it knew that the Society had allowed its membership in the American Federation of Arts to lapse, for this is the only Society that through its magazine furthers interest and appreciation of American ware.

June 6, 1934 KARL LANGENBECK[1]

"Exchange Memberships" with Other Organizations

. . . With the exception of the Art Division, none of the divisions of our Society would find any particular advantage in an alliance with other organizations, but there are many groups interested in ceramic art which are in no way affiliated or in contact with our Society or its Art Division.

The establishment of contacts with these other groups would be highly helpful to the Art Division and to the Society as a whole. The Society might write to the American Federation of Arts and express interest in their work and the belief that its membership would be equally interested in the Art Division activities.

The suggestion that the two groups exchange memberships with no money payments by either party could then be made, each group to designate a representative to take part in meetings and to have a single vote equivalent to the vote of an individual member, and each group to receive without charge all publications of the other.

In this case the official representative might be the Chairman of the Art Division, whoever is in that office, and this representative should be responsible for all contacts such as attending meetings and exhibitions, reviewing literature, etc.

If this suggestion finds favor with the Board of Trustees these "exchange memberships" might be negotiated with other groups, such as the New York Ceramic Society, Clay Club of New York, etc. . . .

June 15, 1934 L. E. BARRINGER[2]

Securing "Equal Thermal History"

I am pleased to receive the copy of your letter to McKinley on "Equal Thermal History" following your letter to Milener in the June *Bulletin* [p. 166]. I find that I have been missing something—the report of the Committee on Industrial Gas Research.

I agree in the main with your experience. In natural gas firing I first relied upon the burners and severely punished the furnace walls, crowns, and bag walls without getting heat into the kiln. It was a sorry mess. I made large openings around the burners for secondary air and, with restricted draft, I got satisfactory results. I carried out gas analyses for several years on both gas and coal firing only a few of which are now available to me. In looking these over I find in the majority of them carbon monoxide and free oxygen.

In my coal firing I made every effort to budget the atmospheric pressure available at the furnace level (I prefer to consider "draft" as "pressure" rather than as "draft"). We have a half-inch water pressure more or less at the furnace mouth and this I tried to conserve in every possible way for use in the kiln room. To this end I endeavored to use as little of it as possible in overcoming furnace resistance.

I used flat grate bars in twin furnaces, though I experimented with other types such as the inclined grates and coking table types. The firing was light and frequent, every fifteen to twenty minutes. The shape and type of grate bar was studied and improved. The furnace doors, a sliding type, were permanently set to leave two inches clearance between the bottom of the door and the door plate. In addition to this secondary air space, the front ends of the grate bars were set to get $1^1/_2$-inch space between them and the front wall of the furnace.

We were producing clear colors—buff, gray, terra cotta, etc., and we wished to avoid flashing. Primarily the furnace setting was for this purpose but incidentally it conserved the available pressure. If one uses too much of this available pressure in getting through the furnace he will have a hot furnace, overfire the top ware (in a downdraft kiln), or get underfired ware in the bottom of the kiln.

The kiln dampers must be used in this pressure conservation, otherwise the greater volume of gas and air entering the kiln and the high velocities will use up the available kiln pressure in the upper setting at the expense of the lower setting.

With damper control we can keep the gas volume and velocities to a desired minimum and thus have a maximum degree of kiln room pressure to develop equal thermal distribution throughout the kiln room.

The discussions, the symposium, will be interesting and valuable if you continue to carry on as you have begun, stirring up interest to the end that the history will be thoroughly considered and its significance in each case clearly brought out. We are not so much interested in how kilns are fired as we are in why they are so fired.

. . . I shall take part in the thermal history discussion.

June 26, 1934 ELLIS LOVEJOY[3]

Another Question Apropos of Uniform Thermal History

I would like to see some research done on the crystal structure at the different temperatures attained in common shales and fire clays in firing to vitrification. At the same time I would like to see parallel runs made with the same clays in which the temperatures have been allowed to drop approximately 100°F, and then run up again 200°. The idea in mind is to determine whether or not there is a "freezing" of the fluxes so they become inactive. It is well known that in firing there are certain stages around 1500° and higher where the shrinkage once stopped by a drop in temperature is hard to start again. The reason, as I see it, is that certain crystals, once they become "set,"

[1] 2501 Kemper Lane, W. H., Cincinnati, Ohio.
[2] General Electric Co., Schenectady, N. Y.
[3] 480 West Sixth Ave., Columbus, Ohio.

are slow to become liquid again and are therefore inactive as fluxes.

There is still another possible reason for this as I see it, that is, the absorption of heat, the fluxing temperatures being decidedly more for some reason when the temperature has been allowed to drop back.

The reason I should like to see this done is because of the very wide difference in coal required to fire a kiln in which the heat has been taken up by steps as compared with the coal required when the heat is raised steadily and not allowed to drop back.

Perhaps there is already research work done which would allow a paper to be written by J. L. Carruthers for the next Meeting covering this subject.

In reading the paper by Morey[4] and the paper by Taylor[5] I seem to see in a vague way the reason for the difficulty in settling after a temperature drop.

June 25, 1934 H. R. STRAIGHT[6]

The following papers are pertinent to this problem: (*a*) E. Orton, Jr., and J. F. Krehbiel, "Influence of Different Feldspars on 'Freezing' Behavior of Cones," *Jour. Amer. Ceram. Soc.*, **11** [4], 215–23 (1928); (*b*) H. B. Henderson and J. H. Caldwell, "Increase in Refractoriness in Ceramic Bodies in Interrupted Heat Treatment," *ibid.*, **11** [11], 795–802 (1928).

EDITOR

REFRACTORIES DIVISION RESEARCH COMMITTEE 1933 PROGRESS REPORT*

The present report consists of two parts, (1) the Committee's activities during the year, and (2) refractories researches at present in progress.

I. COMMITTEE ACTIVITIES

(1) Idealized Geologic Column for Refractory Clays

Wilber Stout of the Ohio State Geological Survey has been interested in this subject for several years. In connection with Dr. Stout's work, Stuart M. Phelps has circulated a questionnaire to the members of the American Refractories Institute.

During the 1933 school year, H. Ries has had a graduate student doing thesis work on this subject. To aid in completing this work Dr. Stout and Mr. Phelps have turned this information over to Dr. Ries.

Dr. Ries tells us that the information on the clays of each state has been submitted to the respective state geologists before including it in the Idealized Geologic Column. It is expected that this report will be ready shortly.

(2) Heat Flow through Furnace Walls

The Committee gave its moral support to the symposium on this subject presented at the Cincinnati Meeting, and has been recommending a complete correlation of the data of this subject, with further symposia at opportune times.

(3) Book on Properties and Uses of Refractories

A book combining properties and uses of refractories in such a way that prospective users and students of chemical engineering and metallurgy can gain a working knowledge of the correct application of refractories in furnaces is contemplated.

Various men interested in the production of a book on refractories are now discussing the writing and publishing of such a book. It is realized that such an undertaking would require the support and coöperation of a considerable number of men in the industry and in the schools.

Further efforts in the production of such a book are being transferred to the Division's Committee on Education, F. A. Harvey, *Chairman*, where this subject more properly belongs.

(4) Properties of Refractories as Related to Their Use

Throughout the year the Committee has encouraged fundamental research on the properties of refractories during and after use, the object of such studies being the better insight into proper application of refractories to furnaces.

(5) Apparatus

The problem of suitable apparatus is always before us; for instance, constant temperature furnaces, using gas or oil as fuel, for temperatures up to cone 33, need study.

II. REFRACTORIES RESEARCH AT PRESENT IN PROGRESS

As old researches are continually being completed or abandoned and new ones started, no attempt has been made to have this list complete. It might be pointed out that much of the information given in the 1930 Report is still reliable, and hence is not repeated here. An effort has been made by this Committee not to publish information which the donors do not want published.

M. F. BEECHER, Norton Co., Worcester, Mass.
- (1) Research on SiC refractories.
- (2) Research on fused alumina refractories.

GEORGE A. BOLE, Ohio Ceramic Industries Association, Columbus, Ohio.
- (1) Release of special shapes from their molds by electrophoresis.
- (2) Production of a lightweight refractory.
- (3) Properties of lightweight refractories.
- (4) Drying special shapes by means of an alternating current.

C. R. FETTKE, Carnegie Institute of Technology, Pittsburgh, Pa.
- (1) Effect of coal ash on boiler refractories.

F. A. HARVEY, Harbison-Walker Refractories Co., Pittsburgh, Pa.
- (1) Effect of gases on refractory materials.

R. A. HEINDL, Bureau of Standards, Washington, D. C.
- (1) Investigation of properties of fireclay brick and the fire clays from which they are prepared. Their plastic flow in flexure under load at 1250°C.

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[4] G. W. Morey, "Glass: The Bond in Ceramics," *Jour. Amer. Ceram. Soc.*, **17** [6], 145–55 (1934).

[5] N. W. Taylor, "Reactions between Solids in the Absence of a Liquid Phase," *ibid.*, pp. 155–63.

[6] Adel Clay Products Co., Adel, Iowa.

* The 1929 Progress Report of this Committee is to be found in *Bull. Amer. Ceram. Soc.*, **13** [5] (Part I), 158 (1930). The 1930 report is to be found in *ibid.*, **14** [7], 199 (1931).

(2) Elastic and strength properties of refractories in tension at room and at elevated temperatures.
(3) Long-time creep tests of refractories at elevated temperatures.
(4) Problems relating to saggers and sagger clays.
(5) The behavior of relatively pure clays on heating.

ROBERT LINTON, Pacific Clay Products Co., Los Angeles, Calif.
(1) L. suggests that research be done on spalling methods, with a view to developing a relationship between air spalling and spalling with air and water vapor.

T. N. MCVAY, University of Alabama, University, Alabama
(1) Microscopic studies on various refractory structures.

S. C. OGBURN, JR., Bucknell University, Lewisburg, Pa.
(1) The mechanical purification of refractory clays.
(2) The effect of certain furnace gases on the refractory properties of clays. (Gases studied thus far include SO_2, N_2, Cl_2, H_2S, CO_2; problem incomplete.)
(3) The chemical analysis of some of the rare elements in fire clays. (Determinations made include zirconium, vanadium, beryllium.)
(4) The effect of iron on the melting point of refractory clay.

S. M. PHELPS, Mellon Institute, Pittsburgh, Pa.
(1) Simplification of panel spalling equipment to make the apparatus as inexpensive to construct as possible.
(2) Effect of heat treatment on the properties of refractories, especially those related to spalling.

GILBERT SOLER, Timken Steel and Tube Co., Canton, Ohio.
(1) Application of present refractories to steel mill service.
(2) Development of new refractories for steel mill service.

R. B. SOSMAN, U. S. Steel Corp., Kearny, N. J.
(1) Thermal conductivity of refractories and refractory insulators.
(2) Properties of the system alumina–silica.

NELSON W. TAYLOR, Pennsylvania State College, State College, Pa.
(1) Study of the mechanism of the chemical attack on mullite by glass batch constituents such as sodium sulfate and sodium carbonate.
(2) Study on the rate of inversion of quartz to cristobalite and of amorphous alumina to corundum.
(3) Study of structural changes in pure minerals at high temperatures.

The Ceramics Department has installed X-ray and petrographic equipment and physicochemical equipment for use in these and similar problems. Several graduate students are now engaged in these researches.

A. E. R. WESTMAN, Ontario Research Foundation, Toronto, Canada.
(1) Testing of clays from Missinaibi River.
(2) Continuing the permeable pressing of clays already reported in *The Journal*.
(3) Developing crucibles for melting cast iron.

H. E. WHITE, Lava Crucible Co. of Pittsburgh, Zelienople, Pa.
(1) Development work on crucibles and special refractories.
(2) Study of the effect of slags and fluxes on refractory structures.

HEWITT WILSON, University of Washington, Seattle, Wash.
(1) At a recent date no refractories researches were reported actively in progress.

The above is a condensed statement of the report given by this Committee at the Cincinnati Meeting.

DONALD W. ROSS, *Chairman*

COMMITTEE: R. A. Heindl, F. A. Harvey, F. H. Norton, Stuart M. Phelps, R. A. Sherman, R. B. Sosman, L. J. Trostel, and Donald W. Ross.

COMMITTEE PERSONNEL

New Chairman of Refractories Division Committee on Data Appointed

Francis J. Williams of the School of Mineral Industries, Pennsylvania State College has been appointed Chairman of the Committee on Data of the Refractories Division, according to the recent announcement of Harold E. White, Chairman of the Refractories Division.

Enamel Division Announces New Committee Names

The following additions to Enamel Division Committees have been made (for complete chart see page 134, *The Bulletin* for May, 1934): *Standards* (*b*), F. E. Hodek, Jr., *Membership*, R. L. McGean, *Data*, E. P. Poste, *Nominations* (Chairman), Murray Gautsch, *Councillors*, Erwin Sohn and William V. Knowles, *Statistics*, William Hogenson.

Electro-Ceramic Research Committee Organized

The personnel of the self-organized, self-motivating committee to investigate and possibly promote electric kiln firing of ceramic ware is as follows: P. D. Helser, *Chairman*, A. V. Bleininger, C. G. Fink, A. F. Greaves-Walker, and S. T. Henry, *Executive Secretary*, Spruce Pine, N. C.

NEW MEMBERS

CORPORATION

N. Clark & Sons, G. D. Clark, Secretary and Treasurer (voter), 116 Natoma St., San Francisco, Calif.
The Glass Industry, J. T. Ogden (voter), 233 Broadway, New York, N. Y.

PERSONAL

Aiken, George W., 5614 Greenspring Ave., Baltimore, Md.; Manager, Carr-Lowrey Glass Co.
Baucom, Frank M., Box 460, Warroad, Minn.; Chemist, Feldspar Products Co.
Burton, Howard B., Jr., 10 Neal Ave., Dayton, Ohio; Research Assistant, Porcelain Dept., Frigidaire Division, Gen. Motors Corp.
Miller, James L., R. D. No. 3, Somerville, N. J.; Asst. Ceramic Engineer, Johns-Manville Corp.
Mueller, Kurt, Ford Inn, Clyde, Ohio; Foreman, Davidson Enamel Products Co.
Offutt, J. James, 706 E. Promenade, Mexico, Mo.; Ceramic Engineer, A. P. Green Fire Brick Co.
Phillips, William E., Oshawa, Ontario, Canada; President, W. E. Phillips Co., Ltd.
Robertson, D. A. W., Box 3407, G. P. O., Sydney, New South Wales, Australia; Mining Engineer.

STUDENT

Cook, Ralph LaVerne, University of Alabama.

Membership Workers' Record

Personal		Corporation	
C. A. Freeman	1	Office	2
C. B. McComas	1		
W. H. Pfeiffer	1	STUDENT	
W. L. Stafford	1		
Office	4	T. N. McVay	1
Total	8	Grand Total	11

ROSTER CHANGES

CORPORATION

American Potash & Chemical Corp., Clark M. Dennis, (voter), 70 Pine St., 50th floor, New York, N. Y. (2 Broadway, New York, N. Y.)

PERSONAL

Arnold, Howard C., 513 Maple Lane, Shields, Pa. (Jenkintown, Pa.)

Ault, Alfred S., 3356 Woodlawn Ave., Wesleyville, Pa. (514 Woodbury Ave., Columbus, Ohio.)

Baldwin, H. Clinton, c/o B. F. Drakenfeld Co., Washington, Pa. (Y. M. C. A., Perth Amboy, N. J.)

Barger, H. D., 1826 E. 82nd St., Cleveland, Ohio. (435 Vermont Place, Columbus, Ohio.)

Bellamy, Harry T., 144 N. Waller Ave., Chicago, Ill. (926 S. Olive, Mexico, Mo.)

Bevis, Ralph E., Ferro Enamel Corp., 4150 E. 56th St., Cleveland, Ohio. (University of Ill.)

Blaha, Emil, 110 Main St., Metuchen, N. J. (111 Brookside Ave., Trenton, N. J.)

Clark, John, 3520 153rd St., Flushing, N. Y. (210 Maxwell Ave., Bayside, Long Island, N. Y.)

Corson, Kenneth P., 2541 15th South, Seattle, Wash. (Taylor, Wash.)

Drake, Arthur D., 36 Bounty St., Metuchen, N. J. (Rockford, Iowa.)

Ferguson, Robert F., c/o Y. M. C. A., 88 Chestnut St., Washington, Pa. (527 Orchard St., Pittsburgh, Pa.)

Greene, Charles F., 218 Melrose Ave., Decatur, Ga. (Thomaston, Ga.)

Haldeman, Virgil K., 1507 N. Alameda St., Burbank, Calif. (330 Whittley Ave., Avalon, Catalina Island, Calif.)

Harman, C. G., 63 E. Armory St., Champaign, Ill. (Ames, Iowa.)

Heffelfinger, George W., Thorndale, Pa. (Coatesville, Pa.)

Hughes, Thomas J., Claysville, Pa. (Lock Box 3, Washington, Pa.)

Hutt, Glenn A., Ferro Enamel Corp., Cleveland, Ohio. (Frigidaire Plant, Dayton, Ohio.)

Johnson, Fred P., 1504 Gardena Ave., Glendale, Calif. (130 West Ave. 31, Los Angeles, Calif.)

Johnson, Paul V., Box 24, Garrett Park, Md. (6712 N. Central Ave., Chevy Chase, Md.)

Jones, Harlow G., Box 52, Hailesboro, N. Y. (6225 Vandyke St., Philadelphia, Pa.)

King, George H., 106 S. 16th St., Philadelphia, Pa. (1210 Genesee Bldg., Buffalo, N. Y.)

Kuechler, Adolph, 50 Richards Rd., Columbus, Ohio. (Montana School of Mines, Butte, Mont.)

Lawton, Lewis H., R. D. No. 1, Titusville, N. J. (509 Broad St., Trenton, N. J.)

Lawler, C. Genevieve, R. No. 6, Webster Groves, Mo. (926 Arcade and Vernon, St. Louis, Mo.)

Layman, Frank E., 86 Orange St., Bloomfield, N. J. (Rm. 418, 75 West St., New York, N. Y.)

Lyon, P. W., Wheeling Steel Corp., Wheeling, W. Va. (American Sheet & Tin Plate Co., Pittsburgh, Pa.)

Maddock, A. M., Titusville, N. J. (Washington Crossing, Trenton, N. J.)

Malinovszky, A., 2759 Santa Ana St., Southgate, Calif. (Malinite Pottery Co., 3049 E. 12th St., Los Angeles, Calif.)

Marley, Henry E., 162 River St., Hornell, N. Y. (University of Cincinnati, Cincinnati, Ohio.)

Martz, Joseph A., McLain Fire Brick Co., Wellsville, Ohio. (P. O. Box 181, Hamburg, N. Y.)

Metzger, Arthur J., Chas. Taylor Sons Co., 706 Burns St., Cincinnati, Ohio. (Ohio State University.)

Petrie, Earl C., Mellon Institute, Pittsburgh, Pa. (Alexandria, Ohio.)

Randall, J. E., Wellsville, N. Y. (414 E. Fall Creek Blvd., Indianapolis, Ind.)

Register, Albert L., Jr., 987 Central Ave., Plainfield, N. J. (Box 293, New Brunswick, N. J.)

Rhodes, Ralph, R., 203 Jacoby St., Morristown, Pa. (15 W. Lane Ave., Columbus, Ohio.)

Rudd, Richard D., 144 E. Bluff St., Marseilles, Ill. (420 W. Roosevelt St., Phoenix, Ariz.)

Snyder, Ray A., Westinghouse Electric & Mfg. Co., Derry Works, Derry, Pa. (Research Dept., Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.)

Wagner, Bruce F., 337 N. Longcommon Rd., Riverside, Ill. (103 Irving Terrace, Kenmore, N. Y.)

Wamsley, Delos H., 16 Harding Ave., North Arlington, N. J. (Alfred Station, N. Y.)

Weightman, Hugh E., 2064 E. 96th St., Cleveland, Ohio. (224 N. 2nd St., DeKalb, Ill.)

Wilson, Howard, S., 218 N. Macomb St., Monroe, Mich. (1257 Northwest Blvd., Columbus, Ohio.)

NOTES AND NEWS

AMERICAN STANDARDS ASSOCIATION SYMBOLS FOR FLUID MEASUREMENTS PREPARED

Insofar as conveniently possible the following symbols have been selected in an attempt to harmonize some of the common commercial usages with those recommended by the American Standards Association for use in hydraulics. In the preparation of such A.S.A. symbol tables certain general rules have been followed. The more important of these rules are as follows:

(1) In general the same symbol shall be used regardless of the system of units.

(2) In cases where more than one system of units is encountered the same symbol should be used with the addition of suitable subscripts or superscripts to denote a unit other than the primary.

(3) The same symbol should be used for a given concept, regardless of the number of special values which occur, and subscripts or superscripts should be used to designate them.

(4) Where possible, capital letters denote total quantities and small letters denote specific quantities or quantities per unit.

(5) Letter subscripts should be used to denote values under special conditions or in special states. (When possible, it is convenient to use descriptive subscript letters.)

(6) Numeral subscripts should be used to denote values at designated points or sections in an apparatus, process, or cycle. In applying numerical subscripts to flowing fluids the general practice is to number from the upstream to the downstream section.

In using numerical subscripts with head meters there are certain conventions which it may be well to state.

The subscript "1" refers to the inlet or upstream section, and very often to the particular section at which the inlet pressure is taken. The subscript "2" applied to A or D very definitely refers to the venturi throat, the parallel portion of a flow nozzle or the orifice opening in a thin plate. When used with p or T the subscript "2" refers to the outlet or downstream section at which p or T is measured, which may be some distance downstream from A_2 and D_2.

Symbol	Symbol Description	Unit
A	Area of section	Sq. ft.
B	Length (width) of weir crest measured at right angle to channel	Foot
b	$= \frac{1}{\sqrt{1-\beta^4}}$, velocity of approach factor	
C	Coefficient of discharge	Ratio
C_c	Coefficient of contraction	Ratio
C_v	Coefficient of velocity	Ratio
C_m	Fraction of test substance in a mixture (concentration)	
c_p	Specific heat at constant pressure	B.t.u. per lb.
c_v	Specific heat at constant volume	B.t.u. per lb.
c_{mp}	Molecular heat at constant pressure ($= c_p \times$ molecular weight)	B.t.u. per lb.-mol. per °F
c_{mv}	Molecular heat at constant volume ($= c_v \times$ molecular weight)	B.t.u. per lb.-mol. per °F
D	Diameter of section[1]	Foot
F	Total pressure, force or load on a section	Pound
f	Function	
G	Specific gravity[2]	Ratio
g	Acceleration due to gravity[3]	Ft. per sec. per sec.
H	Total head	Ft. of fluid[4]
H_t	Heat energy	B.t.u. per hr.
h	Effective differential head	Ft. of fluid[4]
h_{fg}	Latent heat of evaporation	B.t.u. per lb.
h_m	Effective differential head	In. ice cold Hg
h_p	Pressure head (static pressure)	Ft. of fluid[4]
h_v	Velocity head at any point	Ft. of fluid[4]
h_w	Effective differential pressure	In. water at 68°
I	Moment of inertia	
J	Mechanical equivalent of heat	Ft. lb.
K	$= bC$, coefficient of discharge with velocity of approach included	Ratio
k	$= c_p/c_v$, ratio of specific heats	Ratio
L	Length of channel	Foot
M	$= \frac{A}{\sqrt{1-\beta^4}}$, meter constant	
M_w	Molecular weight	
m	Mass	Pound
N	Correction factor (subscript p for pressure, t for temperature)	
p	Intensity of pressure, absolute; the actual or observed (static) pressure[5]	Lb. per sq. in.
p_b	Observed atmospheric pressure (= corrected barometric reading)	Lb. per sq. in.
p_e	Partial pressure of the water vapor in a gaseous mixture	Lb. per sq. in.
p_o	Reference (standard) atmospheric pressure[5]	Lb. per sq. in.
Q	Total volume (as of container; for the account period; for the test)	Cu. ft.
q	Volume rate of flow	Cu. ft. per sec.
q_o	Volume rate of flow at a specified density	Cu. ft. per sec.
R	Gas constant in $144pv = RT$	
R_D	Reynolds' number based on diameter of channel (*i.e.*, on D_1)	
R_d	Reynolds' number based on diameter of orifice, nozzle, or venturi throat (*i.e.*, D_2)	
r	$= p_2/p_1$, ratio of outlet to inlet static pressure	Ratio
T	Absolute (thermodynamic) temperature	°F K
T_a	Observed or "actual" temperature	°F
t	Time interval	Second
u	Internal (or intrinsic) energy	Ft. lb. per lb.
V	Actual (or absolute) velocity	Ft. per sec.
V_m	$= q/A$, mean velocity (speed)	Ft. per sec.
v	$= 1/\rho$, specific volume	Cu ft. per lb.
W	Total weight (of fluid in container; for the account period; for the test)	Pound
W_j	Electric energy	Joule
W_k	Kinetic energy	Ft. lb. per lb.
W_{kt}	Kinetic energy of turbulence	Ft. lb. per lb.
w	Mass (weight) rate of flow, actual	Lb. per sec.
w_t	Mass (weight) rate of flow, theoretical	Lb. per sec.
x	$= \frac{\Delta}{p_1}$, ratio of differential pressure to absolute inlet, static pressure	Ratio
Y	Expansion factor to account for the lateral expansion of a gas jet	
Z	Height from center of gravity of stream to a fixed reference level	Foot
β (beta)	$= D_2/D_1$, ratio of throat or orifice diameter to pipe diameter	Ratio
Δ (delta)	$= p_1 - p_2$, differential pressure	Lb. per sq. in.
ϵ (epsilon)	turbulence factor	Ratio
η (eta)	$= 1 - \frac{\text{molecular weight of water}}{\text{molecular weight of gas}}$	
λ (lambda)	$= \frac{10^6}{R_d}$	
μ (mu)	Absolute viscosity	Lb. per sec.-ft.
ν (nu)	$= \mu/\rho$, kinematic viscosity	
π (pi)	$= 3.14159265$	
ρ (rho)	Density	Lb. per cu. ft.
υ (upsilon)	= nonuniformity factor	
φ	$= \frac{k}{k-1} r^{2/k} \frac{1-r}{1-r} (k-1)/k \frac{1-\beta^4}{1-\beta^4 r^{2/k}}$ = ratio of adiabatic to hydraulic equation	Ratio
ω (omega)	Angular velocity	Radians per sec.

Footnotes

[1]By rule 2 above, when the diameter of a section is given in inches, we may use D' diameter of section (inch).

[2]The specific gravity of a gas shall be taken as the ratio of the weight of a unit volume of the dry gas to the weight of a similar unit volume of dry air free from carbon dioxide, both gas and air being at some standard condition of temperature and pressure. In actual practice it is not uncommon to compare the weights per unit volume under the temperature and pressure conditions existing at the time and place the comparison is made and to neglect any errors introduced by these nonstandard conditions. The density of dry, CO_2 free air, at 32°F, and a pressure of 29.921 in. of ice-cold mercury is 0.080723 lb. per cu. ft.

The specific gravity of a liquid is defined as the ratio of the weight of a unit volume of the liquid to the weight of an equal volume of distilled water, both being at specified temperatures, generally the same temperature. A common temperature of 68°F (= 20°C) is very often used. The density of distilled water at 68°F is 62.3164 lb. per cu. ft.

[3]For most engineering work it is not necessary to distinguish between the exact local value of gravity and the standard value, and it is generally sufficient to use $g = 32.17$ ft. per sec. per sec. However, when for precise work it is necessary to distinguish between the exact local value and the standard value we may use

g_L Acceleration due to gravity, local value = ft. per sec. per sec.

g_0 Acceleration due to gravity, international standard value = 32.1740 ft. per sec. per sec. (= 980.665 cm. per sec. per sec.).

[4]When heads are expressed as "feet of fluid" it is to be under-

stood that such column of fluid is assumed to have an average density equal to that of the flowing fluid at the section of measurement.

[5] Unless otherwise specified, it may be assumed that p_0 represents the international standard value of 1 atmosphere, which is

p_0 = 760 cm. of ice-cold mercury at g_0
= 29.921 in. " " " " "
= 14.696 lb. per sq. in.

Other values for p_0 in more or less common commercial use are:

p_0 = 14.735 lb. per sq. in. = 30.00 in. of ice-cold mercury at g_0; and
p_0 = 14.40 lb. per sq. in., a value often used as a basis for fuel-gas measurements.

SUMMER MEETINGS

Ohio Refractories Group Meets

Twenty-two members of the Refractories Division of the Ohio Ceramic Industries Association held a spring meeting at Zanesville, Ohio, June 7.

The following topics were discussed: "Physical Properties of Insulating Fire Brick," by G. A. Bole, Research Professor, Ohio State University; "Advantages of a Refractory Insulating Brick," by W. M. Hepburn, Vice-President, Surface Combustion Co.; "Application of De-Airing to Refractory Manufacture," by B. T. Bonnot, President, Bonnot Co.; "Weathering of Fire Clays," by C. E. Bales, Ironton Fire Brick Co.

New Jersey Ceramists Meet June 15

The program for the summer meeting of the Ceramic Association of New Jersey held at Asbury Park, N. J., June 15, listed the following papers: "New Applications for Reinforced Brick Masonry," by Judson Vogdes of the New Jersey Brick Manufacturers' Association, and "Ceramics as Related to Modern Architecture," by Ely Jacques Kahn of New York.

CERAMIC SCHOOL NOTES

Pennsylvania Ceramists Support Ceramics at Penn State

Ceramic executives and technical men under the leadership of W. Keith McAfee, President of the American Ceramic Society, met at the School of Mineral Industries, Pennsylvania State College, to inspect the work of the Ceramics Department and to consider means of furthering the program there and making it increasingly useful to the ceramic industry of Pennsylvania.

Roger W. Rowland, President of the New Castle Refractories Co., was unanimously chosen chairman of the advisory board formed by this group.

The board decided to enlist the interest of the ceramic manufacturers and producers of the state and to form an executive committee.

This committee will seek an appropriation for research and improved instruction in ceramics at Pennsylvania State College from the next Pennsylvania legislature.

Thomas Armstrong, President of the Conkling-Armstrong Terra Cotta Co., Philadelphia, and J. M. McKinley, Vice-President of the North American Refractories Co., Cleveland, are members of this committee. Other names will be announced later.

ERRATA

Mr. and Mrs. W. E. Bown, of the Buffalo Executive Committee for the 1935 Meeting, listed on page 164, *The Bulletin* for June, 1934, are in charge of the Ladies Program.

Members of Conference on Glass Problems at the University of Illinois, June 1 and 2.

First row (left to right): Lyon, Schaefer, Henson, Bevis, Thompson, C. L., Klumpp, Silverman, Moore, Parmelee, Hursh. Second row: Greaves-Walker, McK., Ferguson, Hanson, Grubel, Kraner, Arrandale, Linder, Nagle, Fryling, Moyan. Third row: Slater, Grummieaux, Clark, Wampler, Motsch, Crawford, Hopkins, Wright. Fourth row: Tindall, Steinhoff, Kaeppel, Shaver, Fallon, Armstrong, Morgan, Woodward, Thornton. Fifth row: Chesters, Serviss, Babcock, Badger, Andrews, Foster, Brown, Burress.

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PAPER MAKERS IMPORTING CO. INC. EASTON, PENNSYLVANIA, U.S.A.

FINEST POTTERY CLAYS

BUYERS' GUIDE

A

Abrasives (Alundum-Crystolon)
Norton Co.

Aloxite (Refractory Products)
Carborundum Co.

Alumina (Hydrate and Calcined)
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Aluminum Oxide (Fused)
The Exolon Co.
The Vitro Mfg. Co.

Alundum (Refractory Products)
Norton Co.

Ammonium Bifluoride
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Ammonium Carbonate
Ceramic Color & Chemical Mfg. Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Antimony Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

B

Ball Mills
McDanel Refractory Porcelain Co.

Ball Mills (Laboratory Type)
Ceramic Color & Chemical Mfg. Co.

Barium Carbonate
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Hammill & Gillespie, Inc.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Batts
Carborundum Co. (*"Carbofrax Aloxite"*)
Norton Co. (*Alundum Crystolon*)

Bitstone
Potters Supply Co.

Blocks (Refractory)
Carborundum Co.
Norton Co.

Borax
American Potash & Chemical Co.
Drakenfeld & Co., B. F.
Pacific Coast Borax Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Borax Glass
Pacific Coast Borax Co.

Boric Acid (Anhydrous)
Pacific Coast Borax Co.
The Vitro Mfg. Co.

Boric Acid (Crystal, Granular, or Powder)
American Potash & Chemical Co.
Drakenfeld & Co., B. F.
Pacific Coast Borax Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Bricks (Refractory)
Carborundum Co. (*"Carbofrax Aloxite"*)
Norton Co.

C

Carbofrax (Refractory Products)
Carborundum Co.

Carbolon (Refractory Products)
The Exolon Co.

Carbonates (Barium, Lead)
Ceramic Color & Chemical Mfg. Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Caustic Soda
Ceramic Color & Chemical Mfg. Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Cements
Carborundum Co.

Ceramic Chemicals
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Metal & Thermit Corp.
The Roessler & Hasslacher Chemical Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Chromium Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Clay (Ball)
Ceramic Color & Chemical Mfg. Co.
Hammill & Gillespie, Inc.
Paper Makers Importing Co.
Potters Supply Co.
The Roessler & Hasslacher Chemical Co.
Spinks Clay Co., H. C.
The Vitro Mfg. Co.

Clay (China)
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Edgar Brothers Co.
Hammill & Gillespie, Inc.
Paper Makers Importing Co.
The Vitro Mfg. Co.

Clay (Electrical, Porcelain)
Ceramic Color & Chemical Mfg. Co.
Edgar Brothers Co.
Hammill & Gillespie, Inc.
Spinks Clay Co., H. C.
The Vitro Mfg. Co.

Clay (Enamel)
Ceramic Color & Chemical Mfg. Co.
Edgar Brothers Co.
Hammill & Gillespie, Inc.
Metal & Thermit Corp.
Paper Makers Importing Co.
Porcelain Enamel & Mfg. Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Clay (Fire)
Edgar Brothers Co.
Paper Makers Importing Co.
Potters Supply Co.

Clay (German Vallendar)
Ferro Enamel Corp.
Hammill & Gillespie, Inc.
Porcelain Enamel & Mfg. Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Clay Miners
Edgar Brothers Co.
Paper Makers Importing Co.
Spinks Clay Co., H. C.

Clay (Potters)
Hammill & Gillespie, Inc.
Paper Makers Importing Co.
Spinks Clay Co., H. C.

Clay (Sagger)
Edgar Brothers Co.
Paper Makers Importing Co.
Potters Supply Co.
Spinks Clay Co., H. C.

Clay (Wad)
Potters Supply Co.
Spinks Clay Co., H. C.

Clay (Wall Tile)
Hammill & Gillespie, Inc.
Paper Makers Importing Co.
Spinks Clay Co., H. C.

Clocks (Gauge Board)
Ferro Enamel Corp.

Cobalt Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Colors
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Cornwall Stone (Imported)
Hammill & Gillespie, Inc.
Paper Makers Importing Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Crucibles (Filter, Melting, Ignition)
Norton Co.
Potters Supply Co.

Crystolon (Refractory Products)
Norton Co.

D

Decorating Supplies
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Drying Machinery
Ferro Enamel Corp.

E

Enameling Equipment (Complete)
Chicago Vitreous Enamel Products Co.
Ferro Enamel Corp.
Porcelain Enamel & Mfg. Co.

Enameling Furnaces
Carborundum Co. (*Carboradiant*)
Chicago Vitreous Enamel Product Co.
Ferro Enamel Corp.
Norton Co.
Porcelain Enamel & Mfg. Co.

Enameling Iron (Sheet)
American Rolling Mill Co.

Enameling Muffles
Carborundum Co. (*Carbofrax*)
Norton Co. (*Alundum*)

Enameling (Practical Service)
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Ferro Enamel Corp.
Porcelain Enamel & Mfg. Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Enamels
Ceramic Color & Chemical Mfg. Co.
Metal & Thermit Corp.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Enamels (Porcelain)
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Ferro Enamel Corp.
Metal & Thermit Corp.
Porcelain Enamel & Mfg. Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Equipment (Porcelain Enameling)
Chicago Vitreous Enamel Product Co.
Ferro Enamel Corp.
Porcelain Enamel & Mfg. Co.

Exolon (Refractory Products)
The Exolon Co.

BUYERS' GUIDE (continued)

F

Feldspar
Ceramic Color & Chemical Mfg. Co.
Paper Makers Importing Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Fire Brick
Carborundum Co.
Norton Co.

Flint
Paper Makers Importing Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Flint Pebbles
Ferro Enamel Corp.

Floors (Non-Slip)
Norton Co.

French Flint
Paper Makers Importing Co.

Frit
Ceramic Color & Chemical Mfg. Co.
Ferro Enamel Corp.
Porcelain Enamel & Mfg. Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Furnace
Carborundum Co. (*Carboradiant*)
Chicago Vitreous Enamel Product Co.
Ferro Enamel Corp.
Porcelain Enamel & Mfg. Co.

G

Glaze and Body Spar
Ceramic Color & Chemical Mfg. Co.
Paper Makers Importing Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Glazes and Enamels
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Drakenfeld & Co., B. F.
Ferro Enamel Corp.
Porcelain Enamel & Mfg. Co.
The Roessler & Hasslacher Chemical Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Glaze Spar
Ceramic Color & Chemical Mfg. Co.
Paper Makers Importing Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Gold
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Grinding Wheels
Norton Co. (*Alundum Crystolon*)

H

Hearths
Carborundum Co.
(*Carbofrax* heat treating)
Norton Co. (*Crystolon*)

Hearths (High Aluminous Clay, Electrically Sintered Aluminum Oxide, Silicon Carbide)
Carborundum Co.
Norton Co.

I

Iron (Enameling)
American Rolling Mill Co.

K

Kaolin
Ceramic Color & Chemical Mfg. Co.
Edgar Brothers Co.
Hammill & Gillespie, Inc.
Paper Makers Importing Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Kilns (China, Decorating)
Drakenfeld & Co., B. F.

Kryolith
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

L

Leeds (High Aluminous Clay, Electrically Sintered Aluminum Oxide, Silicon Carbide)
Carborundum Co.

Linings (Furnace Refractory, Block Refractory Plate, Brick and Tile)
Carborundum Co.
Norton Co.

M

Magnesia (Sintered, Calcined)
The Exolon Co.
Norton Co.

Magnesite
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Hammill & Gillespie, Inc.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Manganese
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Hammill & Gillespie, Inc.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Metals (Porcelain Enameling)
American Rolling Mill Co.

Minerals
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Muffles (Furnace)
Carborundum Co. (*Carbofrax*)
Ferro Enamel Corp.
Norton Co.

Mullite (Artificial)
The Exolon Co.

N

Nitrates (Cobalt, Sodium)
Ceramic Color & Chemical Mfg. Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

O

Opacifiers
Ceramic Color & Chemical Mfg. Co.
Metal & Thermit Corp.
Porcelain Enamel & Mfg. Co.
The Roessler & Hasslacher Chemical Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Oxides
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Ferro Enamel Corp.
Metal & Thermit Corp.
Porcelain Enamel & Mfg. Co.
The Roessler & Hasslacher Chemical Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

P

Pins
Potters Supply Co.

Porcelain Enameling Service (Practical)
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Ferro Enamel Corp.
Porcelain Enamel & Mfg. Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Porcelain Enamels
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Ferro Enamel Corp.
Porcelain Enamel & Mfg. Co.
The Vitro Mfg. Co.

Potash (Carbonate)
Ceramic Color & Chemical Mfg. Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Pyrometer Tubes (Refractory and Hard Porcelain)
McDanel Refractory Porcelain Co.

R

Refractories
Carborundum Co.
The Exolon Co.
Norton Co.

Refractory Materials
Carborundum Co.
The Exolon Co.
Norton Co.
Titanium Alloy Mfg. Co.

Rutile
Ceramic Color & Chemical Mfg. Co.
Metal & Thermit Corp.
The Roessler & Hasslacher Chemical Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

S

Saggers
Carborundum Co.
Norton Co.
Potters Supply Co.

Selenite of Sodium
Drakenfeld & Co., B. F.
The Vitro Mfg. Co.

Selenium
Drakenfeld & Co., B. F.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Sheets (Enameling Iron)
American Rolling Mill Co.

Silica (Fused)
The Exolon Co.

Silicate of Soda
Ceramic Color & Chemical Mfg. Co.
Philadelphia Quartz Co.
The Vitro Mfg. Co.

Silicon Carbide
The Exolon Co.
Norton Co.

Silicon Carbide Firesand
The Exolon Co.

Sillimanite (Synthetic)
The Exolon Co.

Slabs (Furnace)
Carborundum Co.
Norton Co.

Smelters
Chicago Vitreous Enamel Product Co.
Ferro Enamel Corp.
Porcelain Enamel & Mfg. Co.

Soda Ash
Ceramic Color & Chemical Mfg. Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Sodium Antimonate
Ceramic Color & Chemical Mfg. Co.
Metal & Thermit Corp.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Sodium Fluoride
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Spar
Ceramic Color & Chemical Mfg. Co.
Paper Makers Importing Co.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Spurs
Potters Supply Co.

Stilts
Potters Supply Co.

Sulphuric Acid
Drakenfeld & Co., B. F.

BUYERS' GUIDE (continued)

T

Talc
Hammill & Gillespie, Inc.
Paper Makers Importing Co.
The Roessler & Hasslacher Chemical Co.

Tanks (Pickle)
Ferro Enamel Corp.

Tile (Refractory)
Carborundum Co. (*Carbofrax*)
Norton Co.

Tile (Wall)
Ferro Enamel Corp.

Tin Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Metal & Thermit Corp.
The Roessler & Hasslacher Chemical Co.
The Vitro Mfg. Co.

Titanium
Ceramic Color & Chemical Mfg. Co.
Drakenfeld & Co., B. F.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Titanium Oxide
The Roessler & Hasslacher Chemical Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

Tubes (Insulating)
McDanel Refractory Porcelain Co.
Norton Co.

Tubes (Pyrometer)
McDanel Refractory Porcelain Co.
Norton Co.

W

Wet Enamel
Ceramic Color & Chemical Mfg. Co.
Chicago Vitreous Enamel Product Co.
Ferro Enamel Corp.
Porcelain Enamel & Mfg. Co.
The Vitro Mfg. Co.

Whiting
Drakenfeld & Co., B. F.
Hammill & Gillespie, Inc.
Paper Makers Importing Co.
The Roessler & Hasslacher Chemical Co.

Z

Zirconia
Ceramic Color & Chemical Mfg. Co.
Titanium Alloy Mfg. Co.
The Vitro Mfg. Co.

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Meeting Exacting Operating Requirements

. . . . . Alundum and Crystolon Refractories

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1. **To produce the most nearly perfect firing results obtainable.**
2. **To maintain a low fuel cost per dozen.**
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Alundum (fused alumina) and Crystolon (silicon carbide) refractory materials are used in many tunnel kilns where quality and permanence are essential.

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NORTON COMPANY
Worchester, Mass.
New York Chicago Cleveland

R-483

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Wad Clay
Ground Fire Clay
Bitstone
Fire Brick
Imported Paris White
Domestic Whiting

THE POTTERS SUPPLY COMPANY

EAST LIVERPOOL, OHIO

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ANALYSIS . .

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R. R. Danielson . . . Director of Research